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Online: WPI

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(54) **Method for determining handoff in an environment having macrocells and microcells**

(57) The decision whether to hand off an ongoing call to a macrocell or a neighbouring microcell is made on the basis of how fast the mobile station is travelling. The speed of the mobile station is determined by counting the number of handoffs which have occurred in a preceding period. Another method of determining the speed of the mobile is to count the number of measurement reports occurring in a preceding period. If the speed is above a certain threshold, handoff is to a macrocell rather than a microcell.

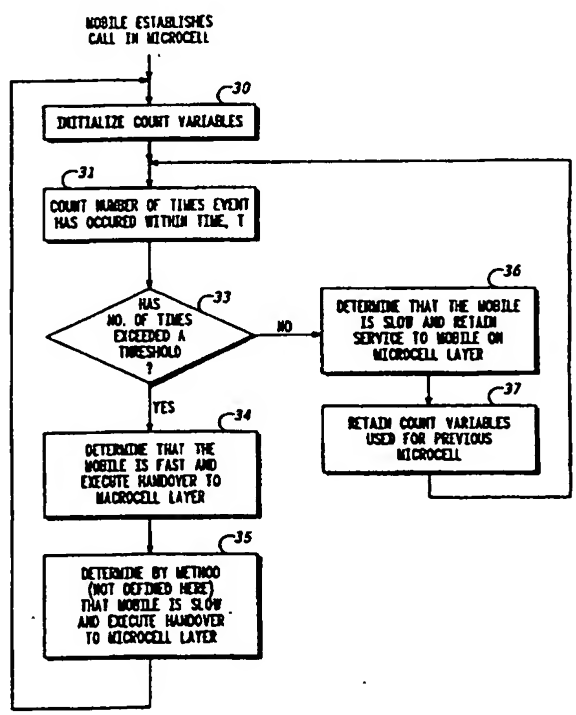

FIG.2

GB 2 301 733 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

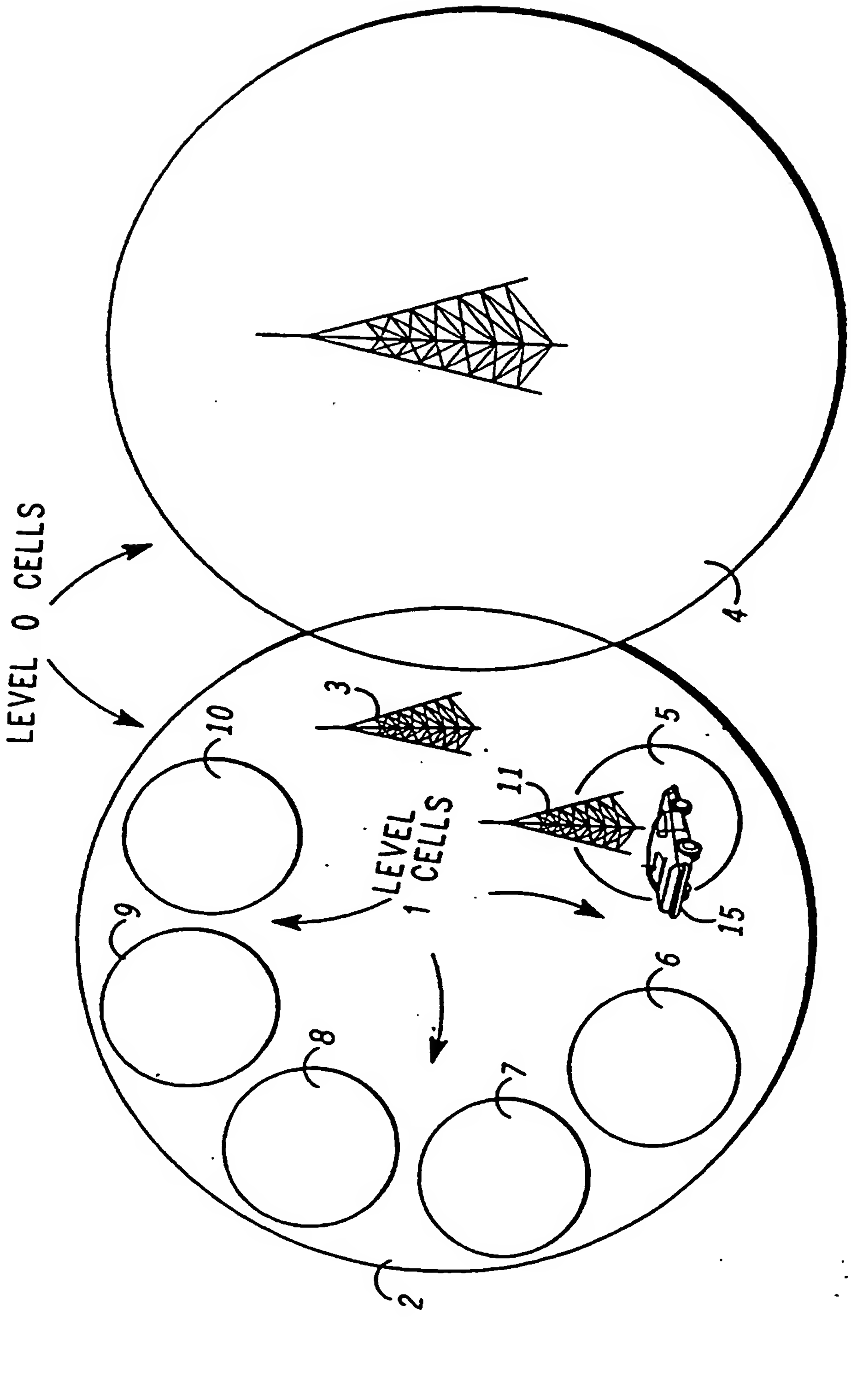

FIG. 1

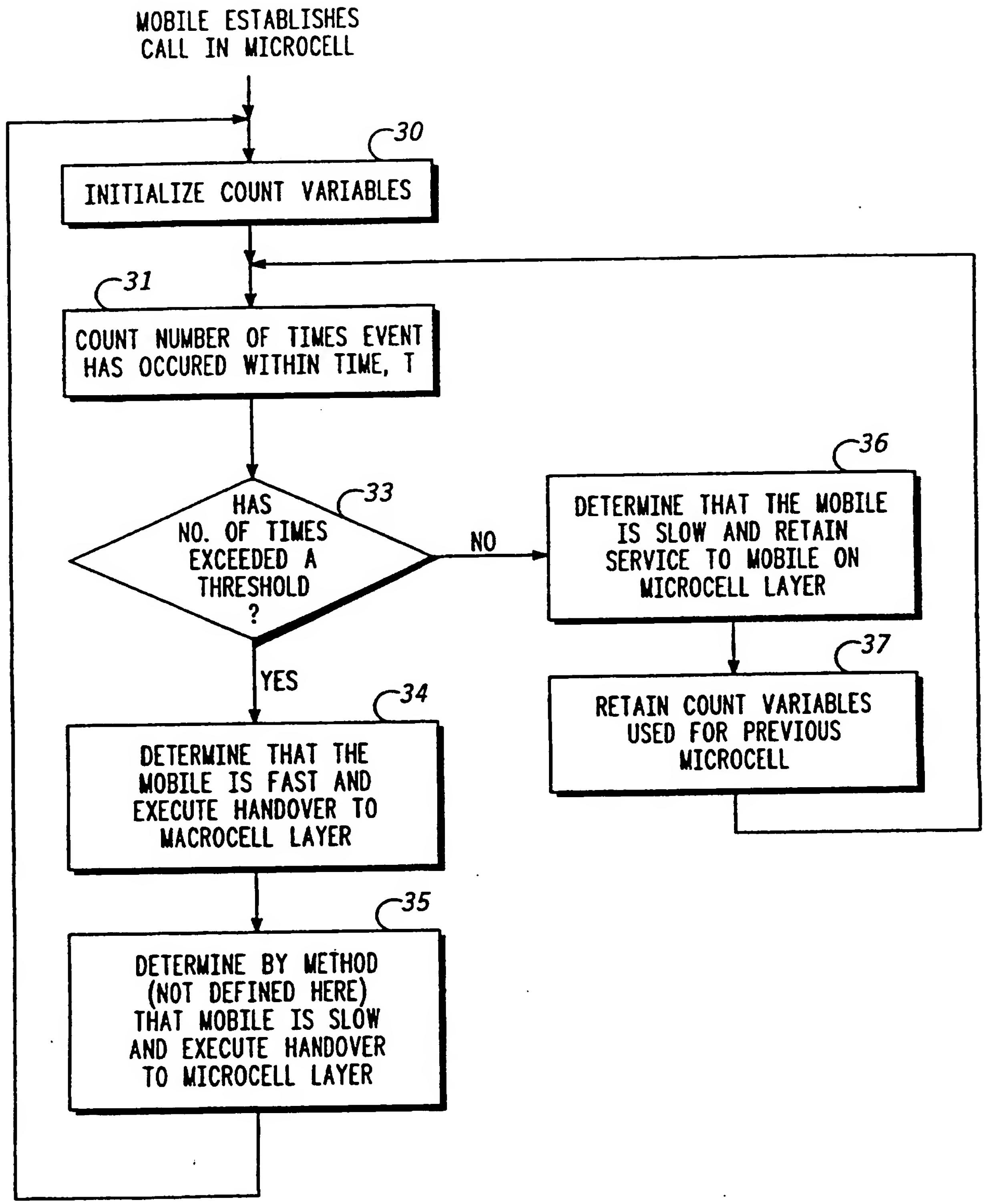
MOBILE ESTABLISHES CALL IN MICROCELL
30
INITIALIZE COUNT VARIABLES
31
COUNT NUMBER OF TIMES EVENT HAS OCCURED WITHIN TIME, T
33
HAS NO. OF TIMES EXCEEDED A THRESHOLD ?
NO
36
DETERMINE THAT THE MOBILE IS SLOW AND RETAIN SERVICE TO MOBILE ON MICROCELL LAYER
37
RETAIN COUNT VARIABLES USED FOR PREVIOUS MICROCELL
YES
34
DETERMINE THAT THE MOBILE IS FAST AND EXECUTE HANDOVER TO MACROCELL LAYER
35
DETERMINE BY METHOD (NOT DEFINED HERE) THAT MOBILE IS SLOW AND EXECUTE HANDOVER TO MICROCELL LAYER

FIG.2

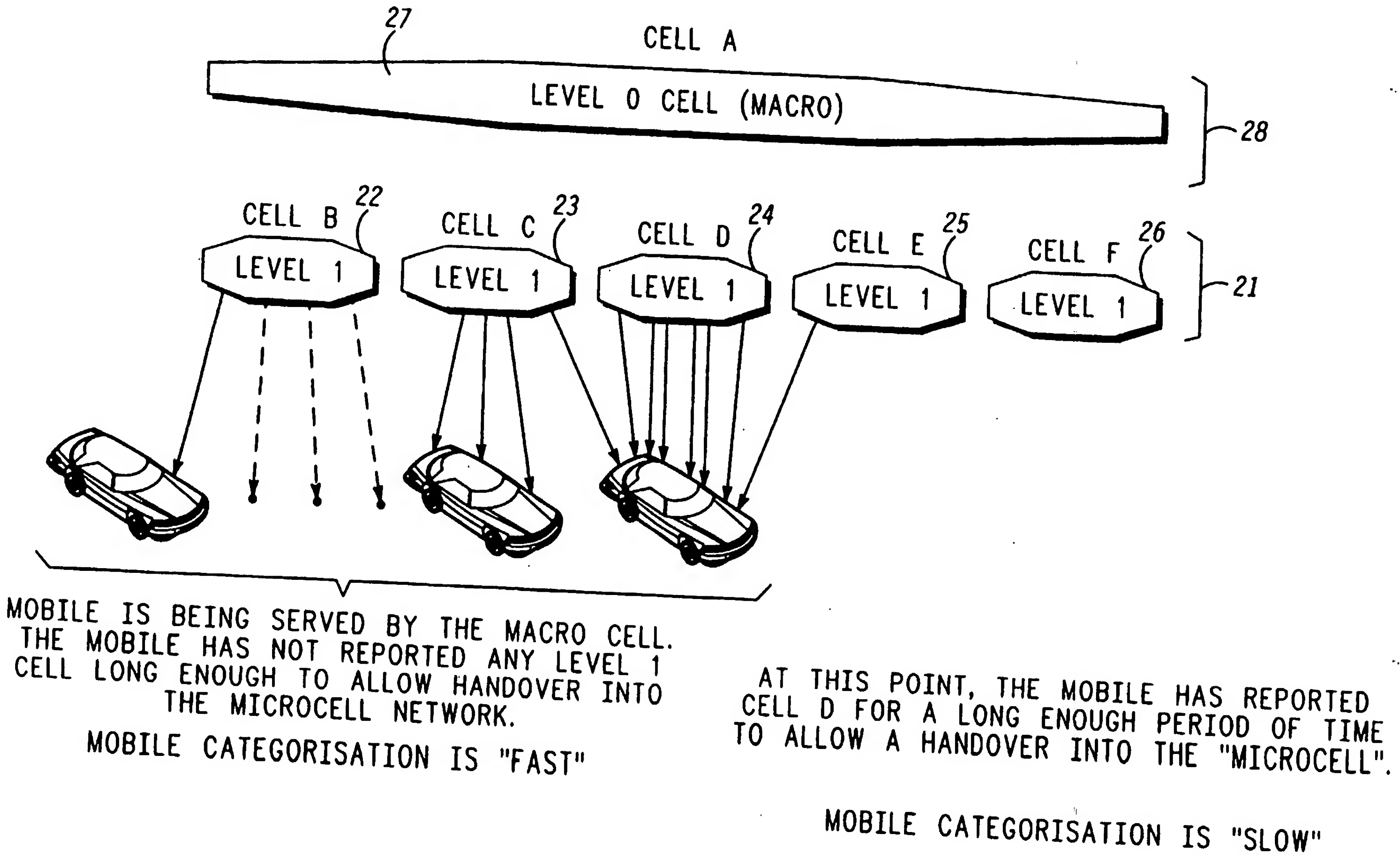
CELL A
LEVEL 0 CELL (MACRO)
27
28
CELL B
CELL C
CELL D
CELL E
CELL F
LEVEL 1
LEVEL 1
LEVEL 1
LEVEL 1
LEVEL 1
22
23
24
25
26
21
MOBILE IS BEING SERVED BY THE MACRO CELL. THE MOBILE HAS NOT REPORTED ANY LEVEL 1 CELL LONG ENOUGH TO ALLOW HANDOVER INTO THE MICROCELL NETWORK.
MOBILE CATEGORISATION IS "FAST"
AT THIS POINT, THE MOBILE HAS REPORTED CELL D FOR A LONG ENOUGH PERIOD OF TIME TO ALLOW A HANDOVER INTO THE "MICROCELL".
MOBILE CATEGORISATION IS "SLOW"

FIG. 3

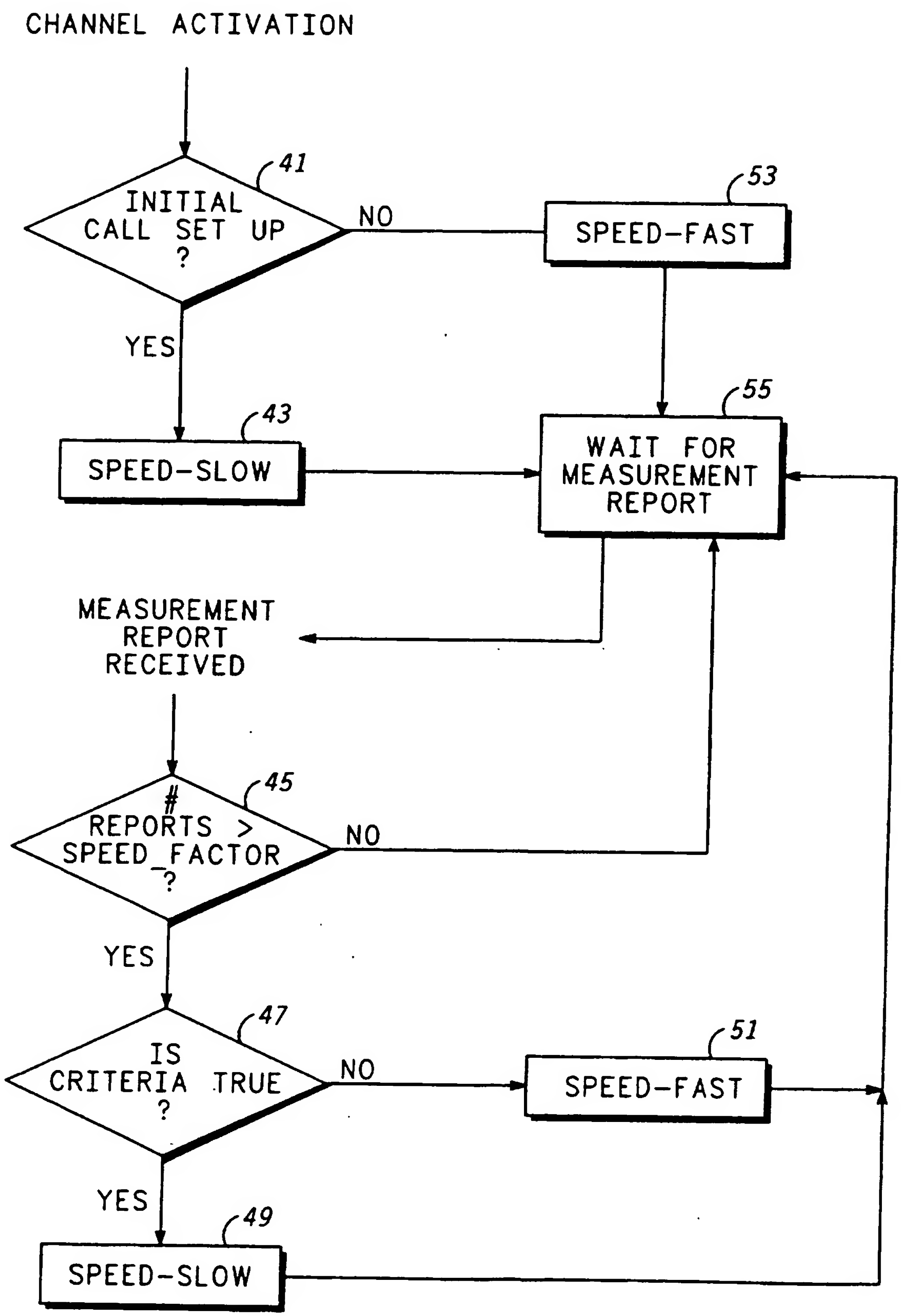
CHANNEL ACTIVATION
INITIAL CALL SET UP ?
41
NO
YES
SPEED-FAST
53
SPEED-SLOW
43
WAIT FOR MEASUREMENT REPORT
55
MEASUREMENT REPORT RECEIVED
REPORTS > SPEED_FACTOR ?
45
NO
YES
IS CRITERIA TRUE ?
47
NO
YES
SPEED-FAST
51
SPEED-SLOW
49

FIG. 4

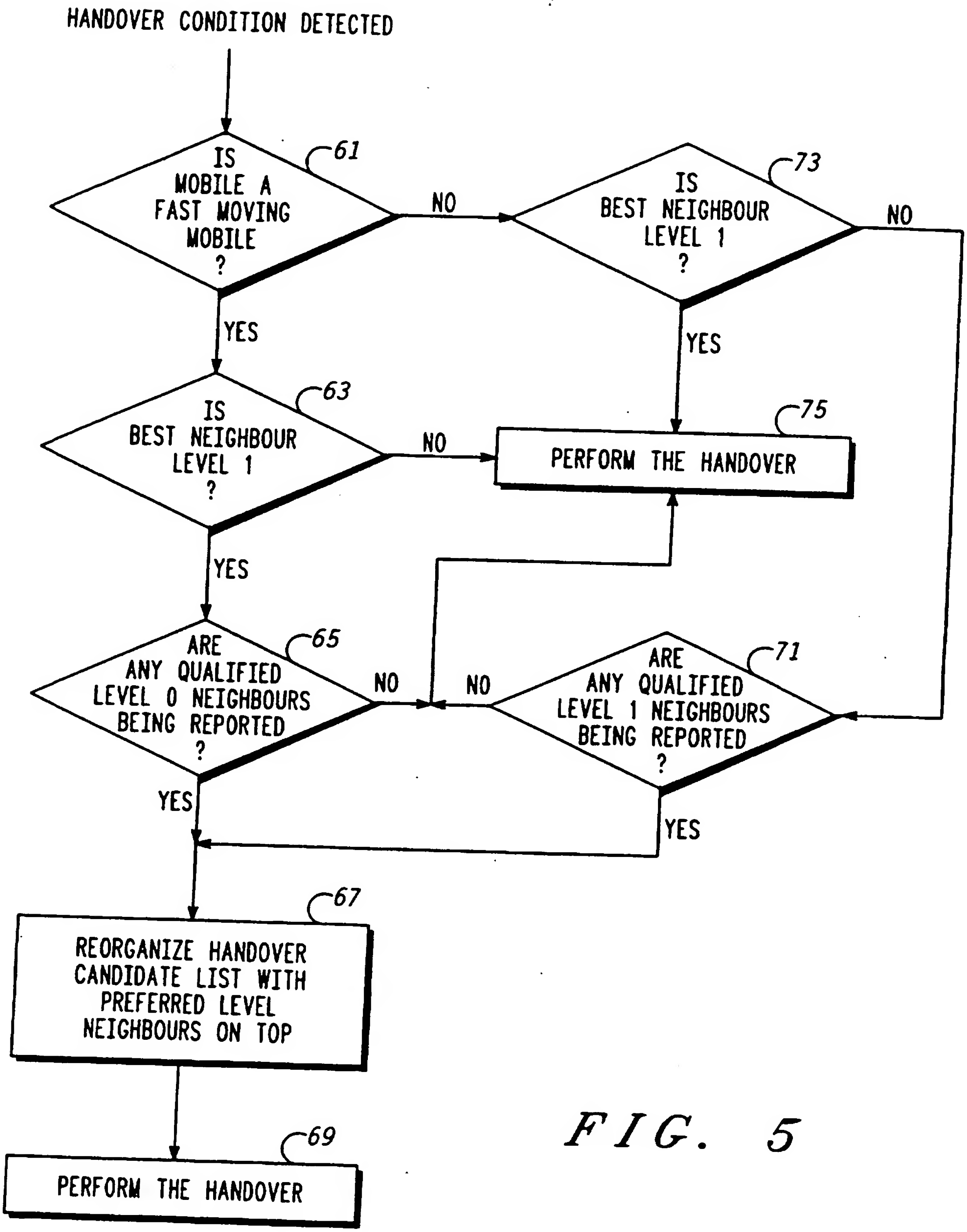
HANDOVER CONDITION DETECTED
IS MOBILE A FAST MOVING MOBILE ?
61
NO
IS BEST NEIGHBOUR LEVEL 1 ?
73
NO
YES
YES
IS BEST NEIGHBOUR LEVEL 1 ?
63
NO
PERFORM THE HANDOVER
75
YES
ARE ANY QUALIFIED LEVEL 0 NEIGHBOURS BEING REPORTED ?
65
NO
NO
ARE ANY QUALIFIED LEVEL 1 NEIGHBOURS BEING REPORTED ?
71
YES
YES
REORGANIZE HANDOVER CANDIDATE LIST WITH PREFERRED LEVEL NEIGHBOURS ON TOP
67
PERFORM THE HANDOVER
69

FIG. 5

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METHOD FOR DETERMINING HANDOVER IN A MULTICELLULAR COMMUNICATIONS SYSTEM

Field of the Invention

This invention relates in general to a method of determining handovers (or handoffs) in a multicellular communications system, and more particularly to determining handovers in a multicellular communications system based on how many times an event occurs.

Background to the Invention

In a cellular environment, at any one time, there is usually one serving cell defined as the cell with the base station that an active mobile station is receiving service from so that the mobile station may receive and transmit communication via the serving cell base station. There are a number of surrounding cells that are neighbouring cells. The serving cell may also be referred to as the cell that the mobile unit is camped on to. In a multicellular environment, there may be cells of different sizes where a number of cells of similar size are located within one larger cell (umbrella cell). The smaller cells within the umbrella cell are called microcells. The umbrella cell may be referred to as a macrocell.

Microcells are created in a dense population of users to allow a greater capacity of users on the cellular system and improve spectral efficiency. The microcells facilitate the reuse of frequencies over a smaller distance. Thus, a mobile unit may be within a microcell as well as an umbrella cell.

Such a two tiered combined cell architecture includes an overlay macrocell layer, comprising of at least one macrocell and an underlay microcell layer, comprising of a plurality of microcells.

For a microcell implementation where the goal is to provide capacity relief for larger cells, there must be a means to determine when a mobile must be handed over to the larger cell (macrocell). To provide effective capacity relief, mobiles may be kept in the microcell network unless it is absolutely necessary to handover to the macrocell network. With a two layered network, it must be determined which of the four types of handovers should be performed.

Microcell to Microcell

Macrocell to Microcell

Handovers to the microcell network are preferred types of handovers. If the mobile is not moving too fast, the best handover candidate is a microcell, even if a signal that the mobile receives from the macrocell is stronger.

Macrocell to Macrocell

If a mobile is being served by a macrocell and is determined to be moving fast, or if no microcells are determined to be a valid candidate for handover, the best handover candidate is another macrocell.

Microcell to Macrocell

For a network that is trying to off load traffic to the microcell network, handing off to the macrocell network is the least desirable type of handover. It should only be performed as a last resort. Justified conditions would be when the quality of the call would otherwise suffer and there are no valid microcells to handover to, or if it has been determined that this is a fast moving mobile and it would be better served by the macrocell.

Some multicellular environments (or communications system) have a problem that fast moving mobile stations will require a large number of handovers when they are served by the microcell layer. A high handover rate can increase the probability of call drop as well as create signalling and processing load on the system. Therefore, it is desirable to serve fast moving mobile stations on the macrocell layer while serving the majority of the traffic on the microcell layer (for increased capacity). Since the preferred layer is the microcell, calls are generally initiated on the microcell layer and moved to the macrocell layer only if they are judged to be fast moving. The issue at hand is how to determine if a mobile station is fast moving? Considering fast moving doesn't necessarily mean a particular velocity rather than a rate of handovers resulting from the mobile station's movement.

It has been suggested that delaying handover decision (the point in time where the system tells the mobile station to change its radio channel to one in another cell) can effectively move fast moving mobiles from the microcell layer to a macrocell in the macrocell layer. When a mobile is served by a microcell, handovers to another microcell are inhibited by a timer (even though the neighbouring microcell is still "better" in terms of being a serving cell for the mobile station). If the timer expires and the

neighbouring cell is still better, the handover is allowed. If while the timer is running, the radio link between the mobile station and the serving cell deteriorates to the point where the call may soon be dropped, a handover is executed to the macrocell layer. Delaying handovers between microcells may not be a desirable way of determining mobile speed. Presumably, the strategy for judging speed is that if the mobile station moves from the point where the neighbouring microcell is "better" than the serving cell to the point where the serving cell's radio link is no longer any good, and the time elapsed between these two points is less than a particular threshold, the mobile is moving fast. Thus, a problem with such an approach is that for a period of time the mobile station is moving fast and is not being served by the best available serving cell, the neighbouring microcell (or macrocell). In other words, during the period where the timer is running the mobile may not be being served by the best cell. Also, the effect on handover loading is not deterministic.

Thus, a method of determining a handover in a multicellular environment needs to be established that allows a mobile station to be constantly served by the best available cell.

Summary of the Invention

According to the present invention, there is provided a method for determining handover for a mobile station in a multicellular communications system having a serving cell and a plurality of neighbouring cells where the serving cell and plurality of neighbouring cells comprise of at least one macrocell and a plurality of microcells, the method includes the steps of counting a number of times an event occurs for the mobile station, and determining a handover to one of the neighbouring cells based on the number counted.

In an embodiment of the invention the event is a measurement report for the mobile station at the serving cell.

In a further embodiment of the invention the event is a handover execution.

Brief Description of the Drawing

FIG. 1 illustrates an example of a multicellular environment.

FIG. 2 is a flow chart for a method according to the present invention.

FIG. 3 illustrates a moving mobile unit in a multicellular environment.

FIG. 4 is a flow chart for a method according to an embodiment of the present invention.

FIG. 5 is a flow chart for a method according to a further embodiment of the present invention.

Detailed Description of the Preferred Embodiment

Referring to FIG. 1, a multicellular (or microcellular) environment is shown comprising of at least one macrocell 2 (or umbrella cell) and a plurality of microcells 5-10. Each cell includes a base station typically located near the geographic centre of the cell. Not all base stations are shown in FIG. 1. A base station typically determines the size and capacity of the cell. A communication system may include different sized cells as well as a mobile station 15 which may be receiving service from either a base station 3 of the macrocell 2 or a base station 11 of one of the microcells 5. Receiving service from a particular base station in terms of being able to receive and transmit calls is also referred to as being camped on that particular base station. When a mobile station establishes a call in one of the microcells, a decision to determine whether the mobile station should stay on the microcellular network or be handed over to the macrocellular network may be dependent upon the speed of the mobile station.

The information required to make an intelligent handover decision is a cell designation (microcell or macrocell) and a "speed" of the mobile. The procedure defined below provides the information required to make the intelligent handover decision.

Designation of a cell layer identifies what network layer a mobile station is currently being served from. The present invention includes a method for specifying what "level" within the network a particular cell belongs. A cell can be categorised into a particular level based on its relative coverage area. A basic microcell implementation can be thought of as a two level implementation. The cells which comprise the largest coverage area (the macrocells 2, 4 in this case) will be designated as level 0, as shown in FIG. 1. The cells whose coverage area falls immediately within that of level 0 cells (the microcells 5-10 in this case) will be designated as level 1. Level 1 cells are a subset of the coverage area of level 0 cells. The level numbers can be used during the decision process to determine the optimum cell to

handover to based on the philosophy that the cells with a higher level number will off load traffic from cells with a lower level number.

Thus, each cell will be assigned a level number in the database. A handover detection process, according to the present invention, will have access to the serving cell's level number as well as all of the reported neighbour cell's level numbers.

It is presumed desirable to maintain calls in cells which have the highest level number. As long as coverage exists from one of the cells with a higher level number, in the higher level cells, the main determining factor in deciding which level the mobile belongs in is the speed of the mobile. It is only necessary to categorise a mobile as either fast or slow. A fast moving mobile can be defined as a mobile whose air interface conditions are changing at a rate that would make it difficult to maintain the call in the microcell network. Similarly, a slow moving mobile is a mobile whose air interface conditions are either steady or changing at a rate that is maintainable within the microcell network.

Thus, there are two distinct speed levels in which a mobile can be categorised. These levels are fast and slow. One way to determine whether a mobile station is fast or slow is count the number of times an event occurs during a period of time. Preferably, the event is one that can be interpreted to relate to speed.

Referring to FIG. 2, a mobile station establishes a call and is served on the microcell network. Count variables are initialised (a counter) as in step 30. The number of times an event occurs for the mobile station is counted within time t, as shown in step 31. For example, if the mobile station is fast moving, the number of handoffs in the microcell layer would be higher than in the case of a slow moving mobile station. Thus, a threshold number of handovers can be determined for a period of time, t. If the number of handovers that occur for the mobile station exceeds the threshold number, as determined in step 33, then the mobile station can be categorised as fast. If categorised as fast the mobile station can be handed over to the macrocell layer as in step 34. The counting may be implemented in the base station, base station controller, or the mobile switching center.

A method (not defined here) may then determine that the mobile station is moving slow and the mobile station may be handed over to a microcell as in step 35. The process is then repeated for the new serving cell by reinitialising the counter, as in step 30.

If the number of handovers do not exceed the threshold number as determined in step 33, then the mobile station can be categorised as slow and be maintained on the microcell layer as in step 36. The count variable are retained and passed on to any new serving microcell, as in step 37. The process of counting can be repeated for the new serving cell, as in step 31. Thus, the counter variables are carried forward when a mobile station moves from microcell to microcell but are initialised when the mobile station begins anew in the microcell layer from either idle mode or handed over from the macrocell layer.

Thus, a handover rate monitor approach as described above is straight forward solution that allows handover decisions to operate as normal (no delays). It simply monitors the rate of handovers that are needed for each mobile and feeds such information to the handover decision process. A mobile with a high rate of handovers can be moved to the macrocell layer.

In a GSM system, a BSC (base station controller) controls a number of cells. A BSC could provide this handover rate monitor provided handovers are only needed between cells controlled by that BSC. If a handover is required to a cell controlled by another BSC, the present state of the monitor would be lost unless this information is transferred to the second BSC. Preferably such handover rate information is transferrable between controllers. An advantage of doing this is that each mobile will be scrutinised for handover rate (in the same way) regardless of whether or not it moves across BSC control area boundaries.

Thus, as aspect of the present invention includes at a common control point (common amongst a number of cells) monitoring a rate at which the system decides to execute handovers. If the rate exceeds threshold, the handover decision is influenced as to where the next handover goes, i.e. the target cell preference is a macrocell.

"State" information of the rate monitor may be exchanged between control points, i.e. when the controller changes, the previous controller provides the history.

A possible implementation includes at a start of call, initialising a count variable (N) to a pre-determined value and starting a timer (T) beginning at a pre-determined value. For each handover executed by the system, decrement N for each expiry of T, increment N and restart timer. If N=O, change preference of handover target candidate or action a handover.

If a handover is executed there is no delay. If a handover is executed to a cell requiring a different point of control, transfer present values for N and T to the new controller.

The reason behind a speed categorisation is to quantify the amount of signal level changes that are likely to happen within the microcell network. If the degree of changes is too high, the number of handovers that are likely to occur during the life of a particular call will increase. Increasing the number of handovers beyond a certain point may cause poor call quality, potential for more dropped calls, and increased signalling traffic through the network. Thus, fast moving mobile stations should be served on the macrocell layer and slow moving mobile stations should be served on the microcell layer.

It is an important aspect of the present invention that handover is not delayed during the counting of handovers or events. Handovers proceed so that the mobile is constantly being served by a desirable cell.

Another event that occurs for a mobile station that can be deterministic of speed is the duration over which it reports the same cell as a neighbour cell, or measurement reports. FIG. 3 shows a multicellular, or microcellular environment. The macrocell layer 28 includes at least one macrocell 27 and may be referred to as a level 0 cell. The microcellular layer 21 includes five microcells 22-26 and may be referred to as level 1 cells. A mobile station 20 is shown as moving through some of the microcells 22-24. In the first two microcells 22, 23 the mobile station 20 is being served by the macrocell because the mobile station 20 did not report any level 1 cell long enough to allow a handover into the microcell network. Thus, the mobile station's categorisation is fast.

The next cell 24 shows that the mobile station has reported a microcell 24 for a longer period of time, thus, allowing a handover to the microcell network, or layer. Furthermore, the mobile station's categorisation is changed to slow.

FIG. 4 shows a flow chart a possible implementation of the present invention. Once a channel has been activated, it is determined whether it is an initial call set up as in step 41. If it is an initial call set up the categorisation speed is set to slow, step 43, and the mobile station is serviced by a microcell in the microcellular network. The base transceiver station (in example, BTS) then awaits a measurement report for the mobile station as

in step 55. If it is not an initial call set up the categorisation speed is set to fast, as in step 53, and then a measurement report is awaited, step 55.

Once a measurement report is received it is counted and the number of measurement reports are compared to a threshold, labelled in step 45 as speed factor threshold. If the number of reports are greater than the speed factor as determined in step 45 criteria is examined as in step 47. The criteria may be such that determines whether the number of measurement reports for a level 1 cell is greater or equal to the threshold speed factor and if such information given to the determination step is reliable or true. If the number of measurement reports for a level 1 cell is greater or equal to the threshold speed factor and if such criteria is true the mobile station's speed categorisation is classified as slow, step 49, and the BTS awaits another measurement report, step 55. If the criteria is not true as determined by step 47 the mobile station's speed categorisation is classified as fast, step 51, and the BTS awaits another measurement report, step 55. The criteria is met if any single level one neighbour is seen by a mobile station for a specified period of time. Thus, the criteria is met if the mobile station reports the same level one neighbour in at least the number of reports specified by the speed factor. In GSM the mobile station has the opportunity to report on the strongest six neighbours every 480 msecs.

Once the "speed" of the mobile station is categorised, such categorisation may be used in the next handover detection process. Referring to FIG. 5, if the mobile is determined to be a fast mobile station as in step 61, it is determined whether the best neighbour level is 1, step 63. If the best neighbour level is 1, it is determined whether there are any qualified level 0 neighbours being reported as in step 65. Qualified may be defined as in terms of GSM or as available in terms of any parameters determined by the system to classify a candidate as qualified. If there are qualified level 0 neighbours being reported, a handover candidate list is reordered, as in step 67, with preferred neighbours on the top. A handover is then executed as in step 69.

If after a handover condition is detected and the mobile station is not determined to be a fast mobile station, it is determined whether there is a best neighbour level 1, as in step 73. If yes, a handover is performed to a microcell, i.e. best neighbour level 1, step 75. If no, it is determined if there are any qualified level 1 neighbours being reported as in step 71. If there are any qualified level 1 neighbours being reported the handover candidate

list is reordered, as in step 67, with preferred neighbours on the top. A handover is then executed as in step 69.

If there are not any qualified level 1 neighbours being reported, step 71 , a handover is performed as in step 75 to the macrocell. If the mobile station is a fast mobile station, step 61, and the best neighbour level is not 1, a handover is performed, as in step 75, to the macrocell. Or, if the best neighbour level is 1 and there are not any qualified level 0 neighbours, as in step 65, a handover is performed to the microcell layer, step 75.

Thus, as discussed above, the speed categorisation can be determined or modified according to the conditions defined below. To be categorised as a slow moving mobile, the following conditions must be met:

Total RXLEV (n(level 1)) reports >= Speed-Factor

RXLEV(n(level 1)) = Signal level reports for a level 1 neighbour cell

Speed-Factor = Threshold for number of measurement report periods that must be received for classification as a SLOW mobile

In GSM, a measurement report period has a duration of 480 msec. Thus, the duration of time is the measurement report period.

It is always preferable to categorise a mobile as a slow moving mobile. Therefore, only if the condition above cannot be met, the mobile will be categorised as a fast moving mobile.

When a channel is activated for initial call setup, the mobile will initially be a slow moving mobile. When a channel is activated as the target channel for a handover, the mobile will initially be a fast moving mobile. This will allow a new call a chance to remain in the microcell network in the case of a quick handover after initial call setup, while preventing a mobile from being "stuck" in the microcell network due to a quick succession of handovers.

The speed categorisation will allow for a modification of the handover candidate list when a hand-over condition is detected. If a mobile is a slow moving mobile, the viable candidate list can be searched to find a level 1 neighbour cell. The level 1 neighbour will be placed in front of the level 0

neighbour to encourage the handover to another cell in the microcell network.

The speed categorisation of a mobile will be re-evaluated every measurement report period. It is for this reason that the method for making the determination must be as simple as possible so as to not incorporate negative performance impacts. From the time of channel activation, a speed categorisation change cannot be made until enough measurement reports have been received to satisfy the condition stated above.

It is important to note that handovers are not delayed by any decision process according to the present invention.

Although the method has been described as being implemented at the base station of the serving cell or base transceiver station, the method could actually be implemented in the mobile unit provided that the required intelligence is built into the mobile unit. The method could also be implemented at the base station of the neighbouring cell provided the proper information was passed to the base station of the neighbouring cell. As cellular systems expand, methods such as the one of the present invention may be chosen to be implemented at higher level control stations.

In conclusion, the present invention provides a method for determining handover in a microcellular communications system that encourages slow moving mobile stations to be served by the microcell network and fast moving mobile stations to be served by the macrocell network. Thus, the number of handovers may be significantly reduced for fast moving mobile stations and the microcellular environment is efficiently utilised. The present invention improves the reliability of handovers resulting in lower number of dropped cells and reduced amount of processing done by the network.

Claims

1. A method for determining handover for a mobile station in a multicellular communications system having a serving cell and a plurality of neighbouring cells where the serving cell and the neighbouring cells comprise of at least one macrocell and a plurality of microcells, the method comprising the steps of:

counting a number of times an event occurs for the mobile station; and

determining a handover to one of the neighbouring cells based on the number counted.

2. The method of claim wherein the event is a measurement report for the mobile station at the serving cell.

3. The method of claim 1 wherein the event is a handover execution.

4. The method of any of the preceding claims wherein the step of determining a handover includes comparing the number of times an event occurs with a threshold number.

5. A method for determining a handover for a mobile station in a microcellular communications system substantially as herein described with reference to FIGs. 2-5 of the drawing.

12

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Relevant Technical Fields (i) UK Cl (Ed.N) H4L (LDSH) (ii) Int Cl (Ed.6) H04Q 7/36, 7/38 **Databases** (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Application number GB 9510847.8 Search Examiner MR N HALL Date of completion of Search 3 JULY 1995 Documents considered relevant following a search in respect of Claims :- 1-5

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2242806 A (STC)	
X	US 5396645 (HUFF) see whole document	1-5

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